Economic Policy Uncertainty and the Yield Curve

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Motivation

General Research Question:

How does economic policy uncertainty affect the yield curve?

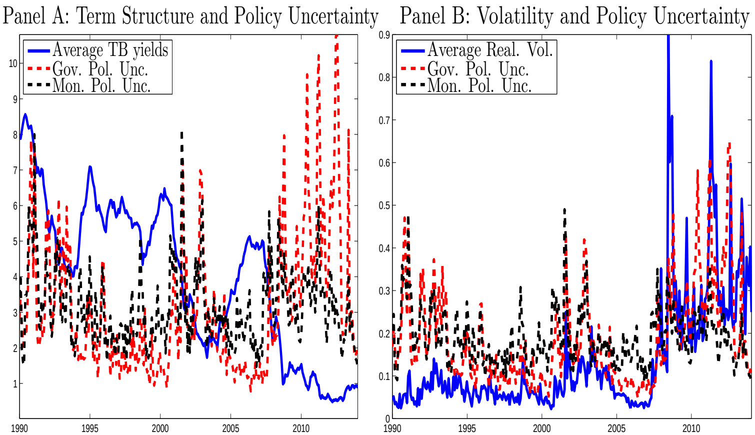
Some examples:

- Government/fiscal policy uncertainty:
  1. Gulf War (invasion of Iraq)
  2. Debt Ceiling crisis in congress and temporary government shutdown
- Monetary policy uncertainty:
  1. Quantitative Easing (QE)
  2. Tapering

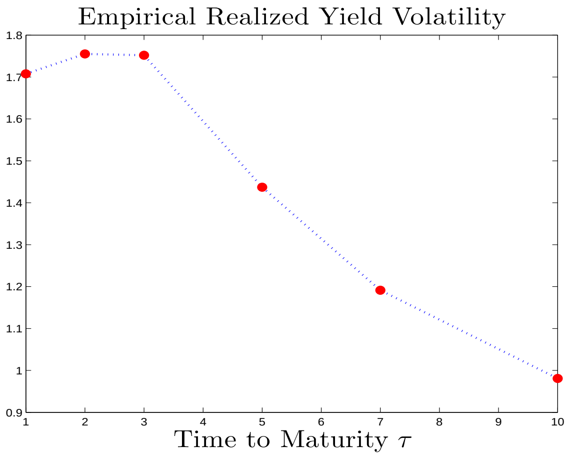
Interpretation: Economic policy uncertainty relates to

- the uncertain impact of a given policy
- AND the uncertainty about which policy the government/central bank is going to implement.

Proxy for policy uncertainty: Index developed by Baker et al. (2012)



- Average correlation between GPU (MPU) and Yields: **-0.43, (-0.01)**
  Increase in government policy uncertainty leads to a decline in nominal bond yields (flight-to-quality)
- Average correlation between GPU (MPU) and realized volatility: **0.54, (0.18)**
  → Increase in policy uncertainty leads to an increase in nominal bond yield volatility



Important observation:

- Unconditional realized bond volatility is hump shaped in time to maturity τ.

Is policy uncertainty key determinant of the shape of bond yield volatility?

Literature Review

1. Affine Term Structure Modeling (in general equilibrium):
    - Cox et al. (1985), Constantinides (1992), Longstaff and Schwartz (1992), Duffie and Kan (1996), Dai and Singleton (2000), Ang and Piazzesi (2003), Duffie et al. (2003), Grkaynak et al. (2005), Buraschi and Jiltsov (2005), Piazzesi and Schneider (2006), Cheridito et al. (2007), Ulrich (2013), Joslin et al. (2014)
2. (Economic) Policy Uncertainty:
    - Durnev (2010), Baker et al. (2012), Boutchkova et al. (2012), Pastor and Veronesi (2012), Bekaert et al. (2012), Julio and Yook (2012), Belo et al. (2013), Pastor and Veronesi (2013), Huang et al. (2013)
3. Bond risk premium:
    - Fama and Bliss (1987), Campbell and Shiller (1991), Cochrane and Piazzesi (2005), Ludvigson and Ng (2009)

Contributions and Results

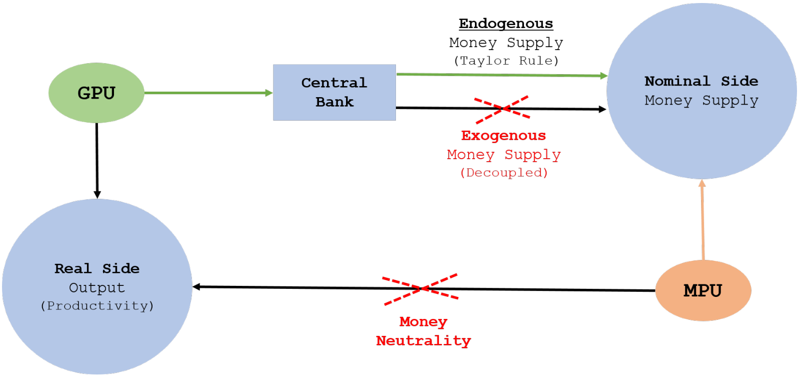
What we do in this paper

- Solving a consumption/investment problem using perturbation methods where there are both, fiscal and monetary policy shocks, and derive the equilibrium yield curve in closed-form
- Capture the flight-to-quality behavior (negative relationship between yields and policy uncertainty), and
- the empirical (hump-) shape of the term structure of bond volatility

Empirical analysis

- Suggests that economic policy uncertainty has a significant effect on both the yield curve and its corresponding term structure of bond volatility

Model Economy



Assumption (The Real Side of the Economy)

$$GDP: \frac{dY_t}{Y_t} = (\mu_y + q_A A_t)dt + \sigma_y \sqrt{\mathbf{g_t}} dW_t^Y, \; Y_0 \in \mathbb{R}_+,$$

$$Prod: dA_t = (\kappa_A(\theta_A - A_t) + \boldsymbol{\lambda} \mathbf{g_t})dt + \sigma_A \sqrt{\mathbf{g_t}} dW_t^A, \; A_0 \in \mathbb{R},$$

$$GPU: \mathbf{dg_t} = \boldsymbol{\kappa_g}\,(\boldsymbol{\theta_g} - \mathbf{g_t})\,\mathbf{dt} + \boldsymbol{\sigma_g}\sqrt{\mathbf{g_t}}\,\mathbf{dW_t^g}, \; g_0 \in (0, \infty)$$

Implications:

- GDP growth is time-varying in productivity A_t whenever $q_A \neq 0$.
- Refer to $\mathbf{g_t}$ as fiscal/government policy uncertainty (GPU).
- Government policy uncertainty negatively affects **long run growth** whenever $\boldsymbol{\lambda} < 0$.
- Government policy uncertainty $\mathbf{g_t}$ is fundamental driver of real risk and long rung growth.

Assumption (Taylor Rule for Money Supply)

$$\frac{dM_t^S}{M_t^S} = \mu_M dt + \eta_1 \left(\frac{dK_t^*}{K_t^*} - \bar{k} dt \right) + \eta_2 \left(\frac{dp_t^*}{p_t^*} - \bar{\pi} dt \right) + \sigma_M \sqrt{\boldsymbol{m_t}} dW_t^M$$

$$\boldsymbol{dm_t = \kappa_m \left(\theta_m - m_t \right) dt + \sigma_m \sqrt{m_t} dW_t^m},$$

where $\mu_M \in \mathbb{R}$ and $\sigma_M > 0$ are the unconditional constant mean and volatility of money growth.

- Parameters $\eta_1 \in \mathbb{R}$ and $\eta_2 \in \mathbb{R}$ determine the weighting of the central bank of the two target growth rates of real output and inflation.
- Active monetary policy if $\boldsymbol{\eta_1 \neq 0}$ and $\boldsymbol{\eta_2 \neq 0}$.
- In equilibrium, economic policy uncertainty affects both capital growth and inflation implicitly.
- Refer to $\boldsymbol{m_t}$ as monetary policy uncertainty. MPU renders central banks money supply volatility state dependent.

Assumption (Preferences of Representative Agent)

$$\mathcal{U}(X_t) = E_t \int_t^{\infty} e^{-\beta(u-t)} U(X_u) du, \beta > 0$$

$$\text{where } U(X_t) = \frac{1}{\gamma}\left(X_t^{\gamma} - 1\right), \; X_t = C_t (M_t^d)^{\xi}, \; 0 \leq \xi \leq 1$$

- γ denotes one minus the coefficient of risk aversion
- When $\gamma = 0$, separable log-preferences: $U(X_t) = \log(X_t)$

Assumption (Capital budget constraint)

The real after-tax return on capital that can either be allocated to consumption C_t or cash balances M_t^d and/or reinvested:

$$C_t dt + M_t^d dt = K_t \frac{dY_t}{Y_t} - \delta K_t dt - dK_t$$

where $K_t \frac{dY_t}{Y_t}$ is total output, $\delta K_t dt$ is capital depreciation with $\delta \in [0,1]$ and dK_t is time t period investment.

Definition (Equilibrium Capital Stock and Money Holdings)

The representative agent's equilibrium is defined as a vector of optimal consumption and money demand controls $[C_t^*, M_t^{d*}]$ and equilibrium price process p_t^* with value function

$$V(t, K_t, A_t, g_t) = \mathbb{E}_t \left[\int_t^\infty e^{-\rho(u-t)} U(C_u, M_u^d) du \right]$$

such that the dynamic HJB programming problem is solved

$$0 = \frac{\partial V(t, K_t, A_t, g_t)}{\partial t} + \max_{\{C_t, M_t^d\}} \left\{ U(C_t, M_t^d) + \mathcal{A} V(t, K_t, A_t, g_t) \right\}$$

and subject to

- representative agent's preferences
- the intertemporal budget constraint
- the monetary policy rule
- money market-clearing $M_t^S = p_t^* M_t^{d*}$
- transversality condition

Proposition (Equilibrium Capital Stock & Money Holdings)

1. *The agent's first order asymptotic optimal controls are*

$$C_t^* = \frac{\beta K_t}{1+\xi}\left[1+\gamma\left(L-g_0(X_t)\right)\right], \; M_t^{d*} = \xi C_t^*.$$

2. *The equilibrium capital accumulation K_t^* and price process p_t^* satisfy*

$$\frac{dK_t^*}{K_t^*} = \mu_{K^*}\left(A_t, g_t\right)dt + \sigma_Y\sqrt{g_t}dW_t^Y$$

$$\frac{dp_t^*}{p_t^*} = \left[\frac{\mu_M - \eta_1\bar{k} - \eta_2\bar{\pi}}{1-\eta_2} + \frac{\eta_1 - 1}{1-\eta_2}\mu_{K^*}\left(A_t, g_t\right) - g_t\frac{(\eta_1-1)\sigma_Y^2}{1-\eta_2}\right]dt + \frac{\sigma_M\sqrt{m_t}}{1-\eta_2}dW_t^M + \frac{(\eta_1-1)\sigma_Y\sqrt{g_t}}{1-\eta_2}dW_t^Y.$$

- $\mu_{K^*}(A_t, g_t) := \mu_Y + q_A A_t - \beta - \delta + \gamma\beta\left(g_0(A_t, g_t) - L\right)$ denotes the equilibrium drift of the capital accumulation process.
- C_t^* and M_t^{d*} are both linear in K_t and X_t.

Equilibrium Term Structure and Bond Risk Premium

1. Nominal Term Structure of Interest Rates

$$Y(t,\tau) = -\frac{1}{\tau}\left(\log(B(t,\tau))\right) = \frac{b_0(\tau)}{\tau} + \frac{b_A(\tau)}{\tau}A_t + \frac{b_g(\tau)}{\tau}g_t + \frac{b_m(\tau)}{\tau}m_t$$

2. The nominal short rate R_t is given by

$$R_t = C_0^R(\gamma) + C_A^R(\gamma)A_t + C_g^R(\gamma)g_t + C_m^R m_t$$

3. The nominal price of fiscal risk $\lambda_t^{N,g}$ as well as the market price of monetary risk $\lambda_t^{N,m}$ are

$$\lambda_t^{N,g} = \frac{\eta_2 - \eta_1}{\eta_2 - 1}\sigma_Y\sqrt{g_t}, \quad \lambda_t^{N,m} = \frac{\sigma_M}{\eta_2 - 1}\sqrt{m_t}.$$

4. The bond risk premium $RP(t,\tau)$ per unit of time is given by

$$RP(t,\tau) := \frac{1}{dt}\mathbb{E}_t\left[\frac{dB(t,\tau)}{B(t,\tau)} - R_t dt\right]$$
$$= \lambda_t^{N,g}\left[b_A(\tau)\rho^{AY}\sigma_A + b_g(\tau)\rho^{gY}\sigma_g\right]\sqrt{g_t} + \lambda_t^{N,m}b_m(\tau)\rho^{Mm}\sigma_m\sqrt{m_t}$$

where $b_g(\tau)$ and $b_m(\tau)$ are time to maturity $\tau = T - t$ functions.

Max. Likelihood Estimation of Feller processes

	GPU			MPU		
	$\hat{\kappa_g}$	$\hat{\theta_g}$	$\hat{\sigma_g}$	$\hat{\kappa_m}$	$\hat{\theta_m}$	$\hat{\sigma_m}$
Estimate	**0.20**	0.93	0.33	**0.42**	0.94	0.29
St. Err.	(0.05)	(0.10)	(0.02)	(0.06)	(0.04)	(0.02)

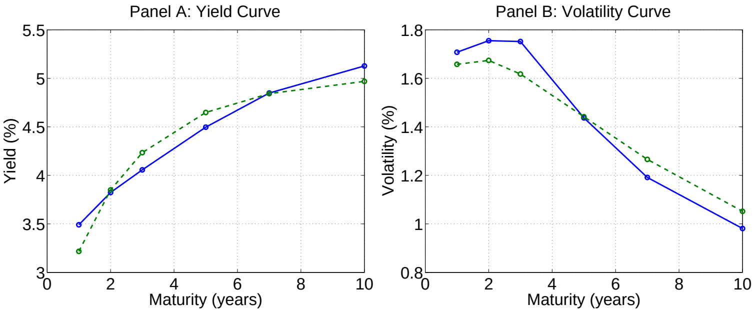
Table: Estim. period is Jan 1990 to Jun 2014 using monthly data.

- Important difference: $\hat{\kappa}_g$ half of $\hat{\kappa}_m$. The half-life of a shock in g_t is $-\log(0.5)/\kappa_g = 1.48$ months (0.72 months for MPU), which implies that it takes a about six weeks (three weeks) for a shock to government (monetary) policy uncertainty to die out by half.
  $\rightarrow$ Government policy shocks more persistent.
- Asymptotic robust standard errors ('Sandwich estimator') of the parameters based on the outer product of the Jacobian of the log-likelihood function.

Model Parameters							
β	0.02	q_A	0.28	σ_M	0.45	κ_A	1.08
ξ	0.85	$\bar{k}$	0.03	ρ^{AY}	0.14	θ_A	4.19
γ	−0.82	$\bar{\pi}$	0.03	ρ^{Ag}	−0.98	σ_A	0.27
δ	0.08	μ_Y	0.38	ρ^{gY}	−0.27	λ	−1.93
η_1	−1.80	σ_Y	0.23	ρ^{Mm}	0.12	A_0	1
η_2	−2.34	μ_M	0.26				

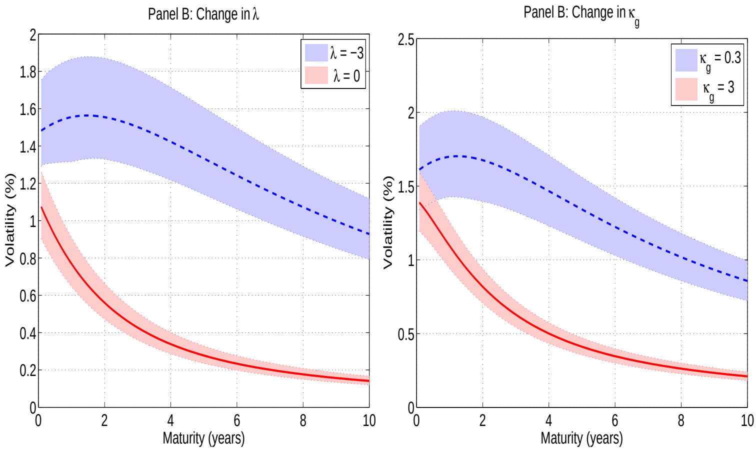
Remarks:

- Parameters in blue calibrated to match simultaneously, the average yield curve and bond volatility curve.
- Parameters in black are computed sample means, variances and covariances.
- Central bank decreases money supply whenever $\left(\frac{dK_t^*}{K_t^*} - \bar{k}dt\right) > 0$ or $\left(\frac{dp_t^*}{p_t^*} - \bar{\pi}dt\right) > 0$ as both $\eta_1, \eta_2 < 0$.
- $\lambda < 0$ and large, implies that fiscal policy uncertainty negatively affects A_t.
- First two centered moments of GDP and money supply growth set to their unconditional estimates.
- Simulation of economy for $N = 2'500$ time steps and number of Monte-Carlo runs is 1'000.



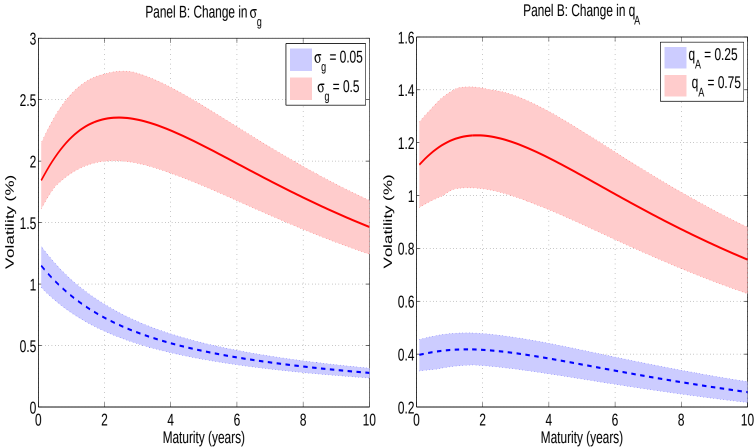
Key observation:

- Model is able to match hump-shape in bond volatility while simultaneously producing a good fit of the term structure.
- Total Error is 7.78 %. Comparison



Remarks:

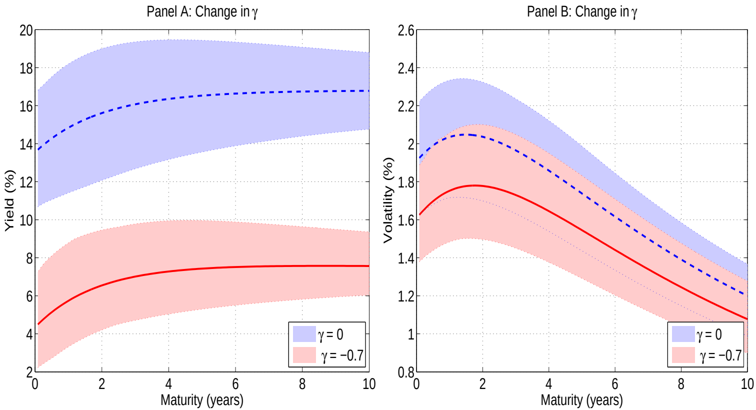
- $\lambda < 0$ crucial to replicate hump in bond volatility curve.
- Persistence of fiscal policy uncertainty shocks need to be high, i.e. κ_g low.



Remarks:

- Magnitude of fiscal policy shock σ_g raises level of bond volatility (hump-shape).
- Time-varying component of GDP growth q_A effects mainly level of bond vol but not its shape.

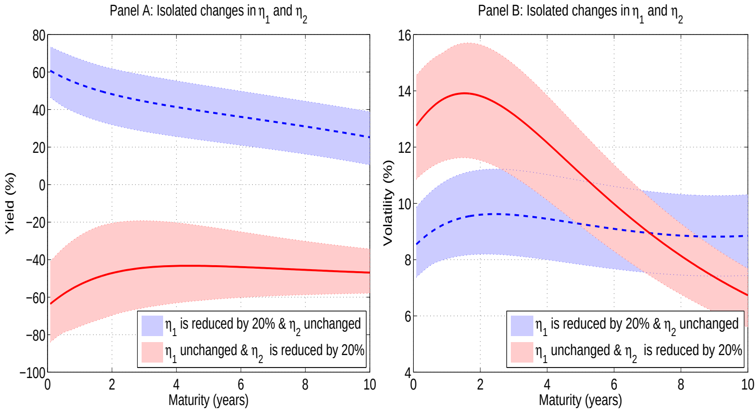
Effect of risk aversion



Remarks:

- Term structure very sensitive to changes in risk aversion. (Flight-to-quality even more pronounced)
- Parallel downward shift of bond volatility curve when risk aversion ↑

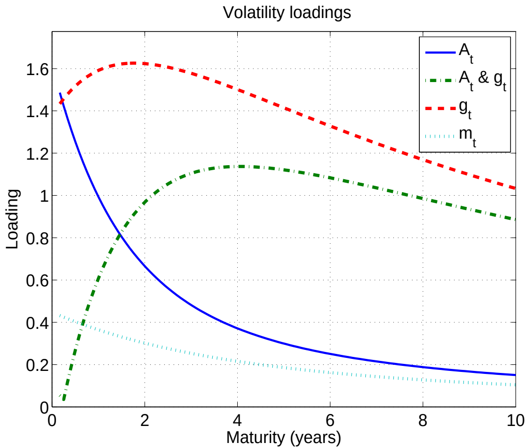
Effect of changing η_1 and η_2



Remarks:

- Shape of yield curve changes substantially if η_1 or η_2 are reduced by 20%.
- Large level and shape effect of vol. if η_1 or η_2 are reduced by 20%.

Where does the hump-shape come from?



Remarks:

- The factor loading on fiscal policy uncertainty and its covariance with productivity A_t are hump-shaped.

Where does the hump-shape come from?

Under some conditions:

- $b_g(\tau)/\tau$ and $\frac{b_A(\tau)}{\tau}\frac{b_g(\tau)}{\tau}$ is hump-shaped (necessary condition).
- Impact of fiscal policy shocks negative, $\lambda < 0$.
- Need both κ_A and κ_g low, mainly κ_g (high persistence of shocks to government policy uncertainty g_t).
- Government impact volatility σ_g is large.
- Stationary variance of g_t and covariance g_t and A_t:
    1. $\mathbb{V}[g_t] = \lim_{T\to\infty} \mathbb{V}_t[g_T] = \frac{\theta_g \sigma_g}{2\kappa_g}$
    2. $\mathbb{C}[A_t, g_t] = \lim_{T\to\infty} \mathbb{C}_t[A_T, g_T] = \frac{\theta_g \sigma_g (2\kappa_g \rho^{Ag} \sigma_A + \lambda \sigma_g)}{2\kappa_g(\kappa_A + \kappa_g)}$

$\rightarrow$ λ **is unconstrained which helps to regulate impact of $\mathbb{C}[A_t, g_t]$ on bond volatility**.

$\rightarrow$ **Both $\mathbb{V}[g_t]$ and $\mathbb{C}[A_t, g_t]$ need to be large**

Testing the model predictions

- **H1**: Higher policy uncertainty decreases nominal yields.

Bond yields are decreasing in g_t or m_t

$$\frac{\partial Y(t,\tau)}{\partial g_t} = \frac{b_g(\tau)}{\tau} < 0, \quad \frac{\partial Y(t,\tau)}{\partial m_t} = \frac{b_m(\tau)}{\tau} < 0, \ \forall \tau \geq 0.$$

→ Main driver of this effect is government policy uncertainty.

$$\left|\frac{b_g(\tau)}{\tau}\right| > \left|\frac{b_m(\tau)}{\tau}\right|$$

- **H2**: Higher policy uncertainty increases nominal yield volatility. This effect is stronger for government policy uncertainty.

$$\frac{b_g^2(\tau)}{\tau^2}\mathbb{V}[g_t] > \frac{b_g^2(\tau)}{\tau^2}\mathbb{V}[m_t]$$

- **H3**: The contribution of government policy uncertainty, i.e. $F^g(\tau) = \frac{b_g^2(\tau)}{\tau^2}\mathbb{V}[g_t]$ to bond yield volatility is hump-shaped.
- **H4**: Bond risk premium is increasing in both monetary $\lambda_t^{N,m}$ and government policy uncertainty $\lambda_t^{N,g}$.

Data summary I

- Monthly TB yields with maturities 1Y, 2Y, 3Y, 5Y and 10Y years from the federal reserve board ranging from January 1990 until June 2014, from which we bootstrap the zero-coupon yield curve treating the treasury yields as par yields.
- Our measure for observed volatility is realized volatility aggregated on a monthly level from business day data.
- Proxy for fiscal and monetary policy uncertainty based on categorical components of EPU index by Baker et al. (2012).

  Government Policy Uncertainty (**GPU**):

  1. News based component (on fiscal policy uncertainty and government spending)
  2. Federal state/local budget disagreement
  3. Tax code expiration

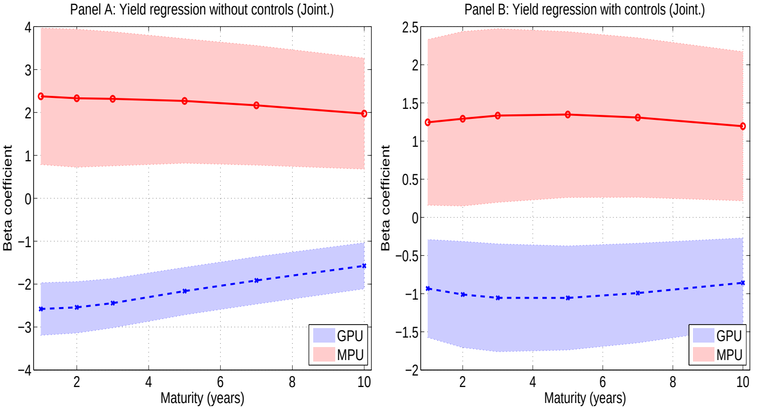
  Monetary Policy Uncertainty (**MPU**):

  1. News based component on monetary policy uncertainty
  2. CPI disagreement

Data summary II

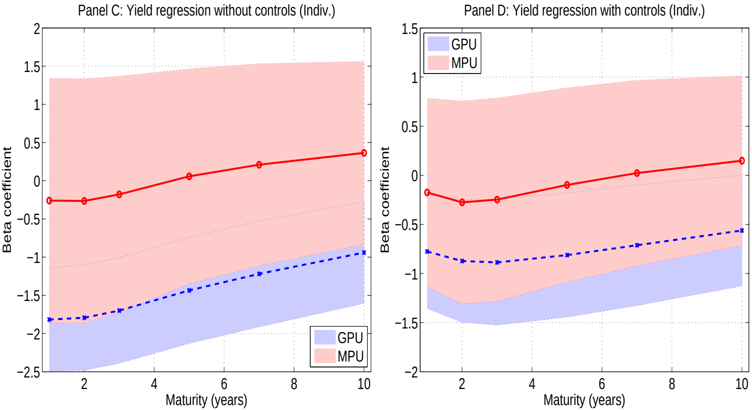
- Two macro factors: industrial production (IP) and Consumer price index (CPI).
- VIX index as a further measure for overall uncertainty
- Control variable for economic activity: Chicago Fed National Activity Index (CFNAI)
- Control variable for bond volatility: Treasury bond implied volatility (TIV) based on weighted average of 1 month options on treasury bonds with maturity 2,5,10 and 30 years
- Standard errors are based on Newey-West (HAC) estimators with three lags.

Bond Yield Regressions I: **Joint**



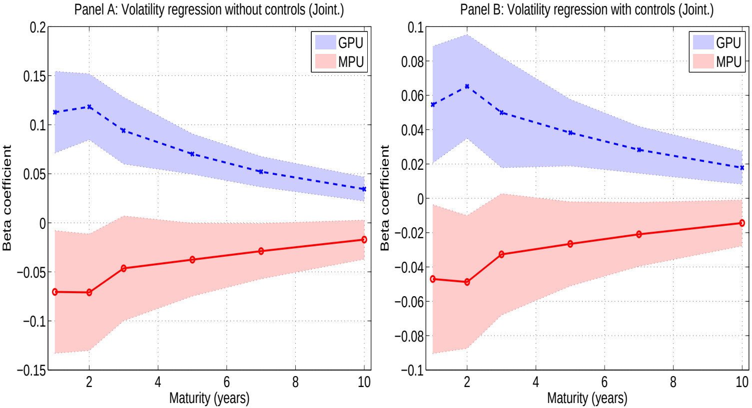
- Increase in government policy uncertainty leads to decline of nominal yields (opposite effect for MPU).
- Reduction is significant along entire term structure for GPU & MPU.
- Average $R^2_{adj} = 0.24$ (simple) and $R^2_{adj} = 0.52$ (with controls).

Bond Yield Regressions II: **Individual**



- Impact of GPU remains negative and significant for any τ, also after including controls (Consistent with **H1**).
- MPU becomes insignificant.
- Average $R^{2,GPU}_{adj} = 0.17$ and $R^{2,MPU}_{adj} = -0.002$ (both simple). Very low predictive power of MPU.

Bond Volatility Regressions I: **Joint**



- Increase in government policy uncertainty leads to an increase in yield volatility (opposite effect for MPU).
- Estimated impact of GPU peaks at 2 year maturity.
- Average $R^2_{adj} = 0.28$ (simple) and $R^2_{adj} = 0.56$ (with controls).

Bond Volatility Regressions II: **Individual**

- Individual impact of GPU remains positive, hump-shaped and significant, also after including controls. (Consistent with **H2** & **H3**.)
- MPU insignificant for any maturity.
- Average $R^{2,GPU}_{adj} = 0.26$ and $R^{2,MPU}_{adj} = 0.024$ (both simple). Very low predictive power of MPU.

H4: Bond excess risk premia

$$RP(t,\tau) := \frac{1}{dt}\mathbb{E}_t\left[\frac{dB(t,\tau)}{B(t,\tau)} - R_t dt\right]$$
$$= \lambda_t^{N,g}\left[b_A(\tau)\rho^{AY}\sigma_A + b_g(\tau)\rho^{gY}\sigma_g\right]\sqrt{g_t}$$
$$+ \lambda_t^{N,m} b_m(\tau)\rho^{Mm}\sigma_m\sqrt{m_t}$$

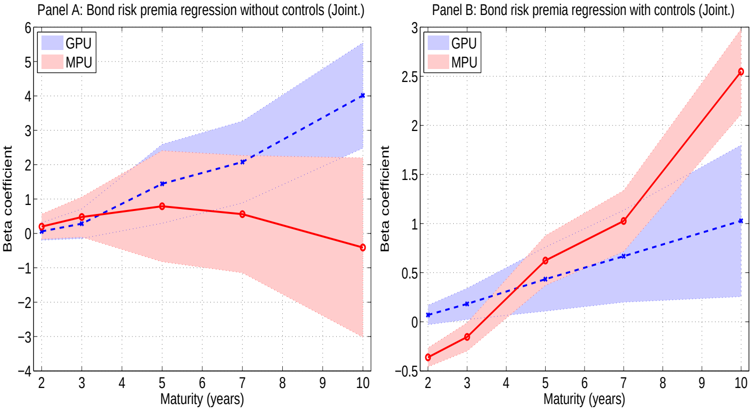
where the real market price of fiscal and monetary uncertainty are given by

$$\lambda_t^{N,g} = \frac{\eta_2 - \eta_1}{\eta_2 - 1}\sigma_Y\sqrt{g_t}, \quad \lambda_t^{N,m} = \frac{\sigma_M}{\eta_2 - 1}\sqrt{m_t}.$$

Model predictions:

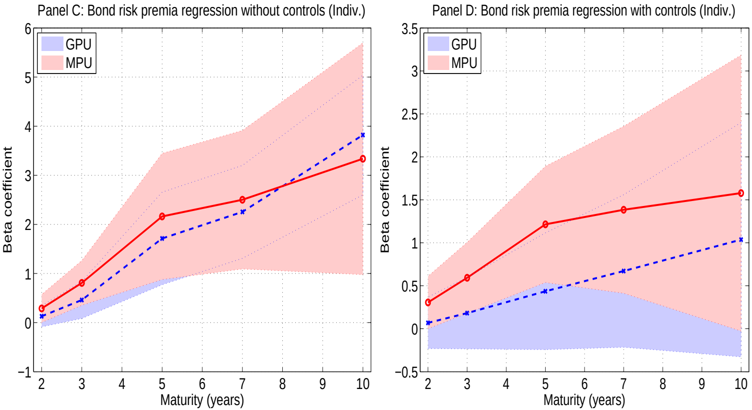
- Time-varying contribution to term premium of both g_t and m_t
- Excess return driven by real and monetary policy uncertainty.

Bond Risk Premia Regressions I: **Joint**



- Positive, significant predictive power of GPU, also after including controls.
- Impact of MPU insignificant for any τ, yet becomes significant after adding controls.
- Average $R^2_{adj} = 0.16$ (simple) and $R^2_{adj} = 0.66$ (with controls).

Bond Risk Premia Regressions II: **Individual**



- Individual impact of GPU and MPU remains positive, increasing and significant (Consistent with **H4**).
- GPU comes insignificant once controlls are added
- Average $R^{2,GPU}_{adj} = 0.08$ and $R^{2,MPU}_{adj} = 0.08$ (both simple). Predictability very comparable of GPU & MPU.

Conclusion

- Derivation of equilibrium model of the nominal term structure of interest rates and corresponding volatility curve using perturbation methods.
- Time-varying long run growth path (GPU) and link between real and nominal side is crucial to
  - replicate hump-shape term structure of bond yield volatility and
  - impact of GPU on bond risk premia.
- Empirical analysis confirm most model predictions:
  1. Higher **GPU** leads to lower yields (flight-to-quality).
  2. Higher **GPU** raises level of bond yield volatility and its contribution is hump-shaped.
  3. **Both fiscal and monetary policy uncertainty** are important predictor of bond risk premia. However, statistical significance of GPU vanishes when controls are added.

Thank You for Your Attention!

Appendix

Optimal Controls: Explicit solutions in the nonperturbed case

First order conditions for optimal consumption and real money holdings are given by

$$C_t^* = \frac{K_t \left(K_t^Q e^{g(X_t)}\right)^{-\gamma}}{\beta Q} \left(\frac{\beta Q \left(K_t^Q e^{g(X_t)}\right)^{\gamma}}{K_t} R \right)^{\frac{\gamma}{\gamma-1}}$$

$$R := \left(\left(-\frac{(\gamma-1)\beta^{\frac{1}{1-\gamma}} Q^{\frac{1}{1-\gamma}} K_t^{\frac{1-\gamma Q}{\gamma-1}} e^{\frac{\gamma g(X_t)}{1-\gamma}}}{\xi} \right)^{\frac{1-\gamma}{\gamma\xi+\gamma-1}} \right)^{-\xi}$$

$$M_t^{d*} = \left(\frac{(1-\gamma)\beta^{\frac{1}{1-\gamma}} Q^{\frac{1}{1-\gamma}} K_t^{\frac{1-\gamma Q}{\gamma-1}} e^{\frac{\gamma g(X_t)}{1-\gamma}}}{\xi} \right)^{\frac{1-\gamma}{\gamma\xi+\gamma-1}} .$$

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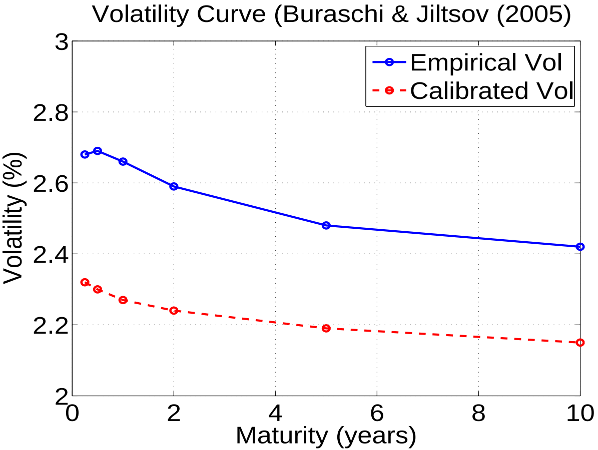
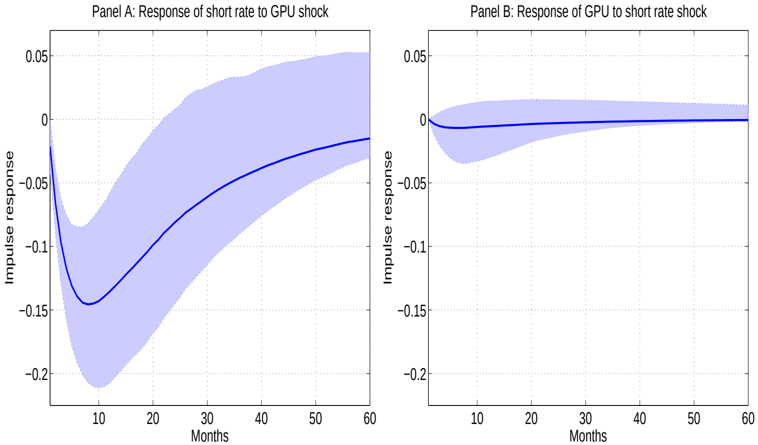


Remarks:

- Estimate their model via quasi-maximum likelihood three moment conditions on yields, inflation and money supply (M2).
- Error is 13.21 % (only volatility term structure).

Go Back

Impulse Response Analysis



- Large negative initial effect of GPU shock on 3M yields, indicates that monetary policy decisions are affected by fiscal (real) shocks.
- Short-rate shock has no impact on GPU.

Proposition (Equilibrium Nominal Term Structure of Interest Rates)

Under time-separable CRRA utility, the nominal discount bond $B(t,\tau)$ with maturity τ is given by

$$B(t,\tau) = \exp\left\{-b_0(\tau) - b_A(\tau)A_t - b_g(\tau)g_t - b_m(\tau)m_t\right\}$$

where

$$b_A(\tau) = C_A \frac{1-e^{-\kappa_A \tau}}{\kappa_A} \ ,$$

$$-b_g^{'}(\tau) = Z_{0g}(\tau) + Z_{1g}(\tau) b_g(\tau) + Z_{2g} b_g^2(\tau) \ ,$$

$$b_m(\tau) = \frac{-Z_{1m} + H_m Cot\left(\frac{1}{2}\left(-H_m\tau - Tan\left(\frac{2\sqrt{Z_{0m}Z_{2m}}}{H_m}\right)\right)\right)}{2Z_{2m}} \ ,$$

$$b_0(\tau) = \int_0^\tau C_0(u)du$$

with $H_m = 4Z_{0m}Z_{2m} - Z_{1m}^2$, and the constant parameters $Z_{0m}, Z_{2i}, i \in \{g,m\}$ and $Z_{0g}(\tau), Z_{1g}(\tau), C_0(\tau)$ are time-to-maturity functions that only depend on the structural model parameters of the economy.

Bond Yield Regressions I

n	3M	6M	1Y	2Y	3Y	5Y	7Y	10Y
EPU	-1.574	-1.621	-1.637	-1.651	-1.599	-1.442	-1.304	-1.128
t_{EPU}	(-12.98)	(-13.46)	(-13.94)	(-15.23)	(-16.53)	(-17.22)	(-16.16)	(-14.48)
R^2_{adj}	0.459	0.469	0.490	0.514	0.525	0.506	0.471	0.423
VIX	-0.423	-0.418	-0.429	-0.459	-0.456	-0.434	-0.391	-0.368
t_{VIX}	(-2.17)	(-2.14)	(-2.25)	(-2.47)	(-2.56)	(-2.67)	(-2.55)	(-2.66)
R^2_{adj}	0.026	0.024	0.026	0.031	0.033	0.035	0.032	0.035
EPU	-1.553	-1.600	-1.615	-1.621	-1.566	-1.412	-1.281	-1.098
t_{EPU}	(-12.18)	(-12.57)	(-13.11)	(-14.43)	(-15.78)	(-16.86)	(-15.96)	(-14.33)
VIX	-0.084	-0.08	-0.09	-0.12	-0.14	-0.146	-0.113	-0.126
t_{VIX}	(-0.500)	(-0.495)	(-0.554)	(-0.803)	(-0.982)	(-1.104)	(-0.890)	(-1.092)
R^2_{adj}	0.462	0.471	0.492	0.519	0.533	0.517	0.478	0.431

Implications;

- Increase in economic policy uncertainty leads to a decline of nominal yields.
- Reduction is significant along entire term structure.
- Statistical significance of VIX vanishes when EPU index is included into the regression equation.

Bond Yield Regressions II: Adding Macro Variables

n	3M	6M	1Y	2Y	3Y	5Y	7Y	10Y
EPU	-1.498	-1.547	-1.566	-1.580	-1.532	-1.388	-1.263	-1.087
t_{EPU}	(-14.65)	(-15.08)	(-15.73)	(-17.09)	(-18.18)	(-18.02)	(-16.38)	(-14.28)
IP	0.490	0.473	0.477	0.454	0.405	0.312	0.247	0.210
t_{IP}	(4.90)	(4.73)	(4.74)	(4.48)	(4.09)	(3.29)	(2.62)	(2.35)
R^2_{adj}	0.535	0.541	0.571	0.604	0.609	0.562	0.505	0.450
EPU	-1.377	-1.415	-1.443	-1.470	-1.437	-1.304	-1.177	-1.005
t_{EPU}	(-11.34)	(-11.65)	(-12.15)	(-13.17)	(-14.04)	(-14.55)	(-13.60)	(-12.0)
CPI	0.846	0.869	0.831	0.801	0.757	0.708	0.661	0.634
t_{CPI}	(4.50)	(4.66)	(4.54)	(4.24)	(4.00)	(3.86)	(3.65)	(3.74)
R^2_{adj}	0.567	0.578	0.585	0.597	0.598	0.582	0.548	0.512
EPU	-1.365	-1.405	-1.437	-1.469	-1.437	-1.301	-1.175	-1.004
t_{EPU}	(-13.20)	(-13.37)	(-14.08)	(-15.22)	(-15.91)	(-15.72)	(-14.28)	(-12.36)
IP	0.290	0.277	0.287	0.251	0.198	0.106	0.063	0.028
t_{IP}	(1.66)	(1.59)	(1.64)	(1.43)	(1.17)	(0.68)	(0.43)	(0.20)
CPI	0.770	0.799	0.753	0.723	0.690	0.678	0.646	0.628
t_{CPI}	(3.63)	(3.83)	(3.66)	(3.43)	(3.33)	(3.47)	(3.38)	(3.55)
R^2_{adj}	0.582	0.591	0.600	0.608	0.603	0.582	0.547	0.510

Intermediary conclusion;

- Statistical significance of EPU index remains high.

Bond Yield Regressions II: Term Structure of Bond Yield Volatility

		3M	6M	1Y	2Y	3Y	5Y	7Y	10Y
IP	EPU	0.261	0.273	0.240	0.200	0.171	0.116	0.066	0.016
	t_{EPU}	(8.62)	(9.15)	(9.20)	(9.47)	(10.30)	(10.05)	(5.72)	(1.22)
	VIX	-0.151	-0.157	-0.136	-0.124	-0.109	-0.088	-0.079	-0.050
	t_{VIX}	(-3.21)	(-3.36)	(-3.36)	(-3.57)	(-3.92)	(-5.08)	(-5.44)	(-4.19)
	IP	-0.054	-0.054	-0.033	-0.020	-0.007	0.015	0.023	0.039
	t_{IP}	(-1.68)	(-1.66)	(-1.16)	(-0.91)	(-0.37)	(1.35)	(2.25)	(3.71)
	R^2_{adj}	0.360	0.386	0.387	0.376	0.411	0.471	0.364	0.308
Infl.	EPU	0.270	0.281	0.248	0.207	0.176	0.117	0.064	0.014
	t_{EPU}	(9.45)	(9.97)	(10.22)	(10.59)	(11.57)	(10.66)	(5.64)	(1.04)
	VIX	-0.113	-0.118	-0.104	-0.102	-0.097	-0.092	-0.089	-0.065
	t_{VIX}	(-2.31)	(-2.41)	(-2.49)	(-2.95)	(-3.57)	(-5.74)	(-6.51)	(-4.84)
	CPI	0.059	0.065	0.060	0.047	0.035	0.015	0.004	0.002
	t_{CPI}	(1.28)	(1.48)	(1.61)	(1.59)	(1.56)	(0.93)	(0.20)	(0.11)
	R^2_{adj}	0.352	0.377	0.394	0.382	0.418	0.469	0.347	0.208
Full	EPU	0.256	0.270	0.240	0.204	0.175	0.117	0.065	0.015
	t_{EPU}	(9.14)	(9.80)	(9.97)	(10.60)	(11.63)	(10.49)	(5.54)	(1.09)
	VIX	-0.137	-0.141	-0.120	-0.114	-0.103	-0.087	-0.080	-0.051
	t_{VIX}	(-3.03)	(-3.15)	(-3.06)	(-3.46)	(-3.93)	(-5.15)	(-5.35)	(-4.12)
	IP	-0.090	-0.091	-0.063	-0.039	-0.019	0.012	0.026	0.045
	t_{IP}	(-2.34)	(-2.39)	(-1.87)	(-1.50)	(-0.91)	(0.91)	(2.01)	(3.63)
	CPI	0.098	0.105	0.087	0.062	0.042	0.011	-0.007	-0.017
	t_{CPI}	(2.19)	(2.41)	(2.27)	(2.01)	(1.71)	(0.59)	(-0.41)	(-1.02)
	R^2_{adj}	0.390	0.422	0.427	0.390	0.422	0.468	0.364	0.310

Bond Yield Regressions II: Term Structure of Bond Yield Volatility

Some remarks:

- EPU index remains significant along entire term structure (except $\tau = 10$) $\rightarrow$ In line with H2
- After adding further control variables, magnitude of EPU index remains roughly the same.
- Point estimates of EPU index indicate hump-shape contribution. (highest at 6M maturity) $\rightarrow$ In line with H3.
- IP and CPI are only significant for some selected tenures τ.
- Adding macro variables does not increase the R^2_{adj} significantly.

Decomposing the EPU index: Yield Regressions with macro variables

n	3M	6M	1Y	2Y	3Y	5Y	7Y	10Y
EPU^g	-1.130	-1.167	-1.191	-1.253	-1.250	-1.203	-1.118	-0.995
t_{EPU^g}	(-7.89)	(-7.99)	(-8.19)	(-8.91)	(-9.35)	(-9.62)	(-9.13)	(-8.42)
EPU^r	-0.468	-0.474	-0.473	-0.410	-0.344	-0.184	-0.111	-0.021
t_{EPU^r}	(-3.10)	(-3.09)	(-3.10)	(-2.65)	(-2.24)	(-1.21)	(-0.73)	(-0.14)
VIX	0.372	0.375	0.351	0.271	0.203	0.085	0.057	-0.012
t_{VIX}	(2.30)	(2.37)	(2.25)	(1.70)	(1.30)	(0.58)	(0.40)	(-0.10)
IP	0.338	0.331	0.328	0.290	0.231	0.156	0.119	0.074
t_{IP}	(1.83)	(1.77)	(1.76)	(1.54)	(1.26)	(0.91)	(0.71)	(0.48)
CPI	0.864	0.893	0.851	0.801	0.754	0.687	0.643	0.604
t_{CPI}	(3.98)	(4.17)	(4.02)	(3.67)	(3.50)	(3.35)	(3.23)	(3.27)
R^2_{adj}	0.597	0.607	0.615	0.614	0.607	0.579	0.547	0.514

Observations:

- Indicates that only uncertainty with respect to government policy remains significant (for all τ).
- Uncertainty not related to government policy becomes insignificant (long end).
- Explanatory power remains high (R^2_{adj}'s are almost identical).

Decomposing the EPU index: Yield Volatililty Regressions including Macro Variables

τ	3M	6M	1Y	2Y	3Y	5Y	7Y	10Y
GPU	0.310	0.332	0.296	0.239	0.197	0.118	0.059	0.006
t_{GPU}	(7.35)	(7.50)	(7.54)	(7.41)	(7.70)	(7.13)	(4.14)	(0.42)
MPU	-0.098	-0.084	-0.072	-0.052	-0.034	-0.002	0.009	0.016
t_{MPU}	(-2.00)	(-1.73)	(-1.69)	(-1.48)	(-1.21	(-0.13)	(0.58)	(1.06)
VIX	-0.069	-0.080	-0.067	-0.072	-0.073	-0.077	-0.079	-0.056
t_{VIX}	(-1.42)	(-1.66)	(-1.56)	(-2.01)	(-2.57)	(-4.26)	(-5.25)	(-4.38)
IP	-0.091	-0.091	-0.062	-0.046	-0.025	0.009	0.025	0.048
t_{IP}	(-2.77)	(-2.79)	(-2.14)	(-1.97)	(-1.36)	(0.70)	(1.93)	(3.79)
CPI	0.102	0.107	0.088	0.072	0.051	0.014	-0.007	-0.021
t_{CPI}	(2.44)	(2.62)	(2.46)	(2.45)	(2.13)	(0.75)	(-0.38)	(-1.24)
R^2_{adj}	0.414	0.438	0.439	0.416	0.448	0.470	0.361	0.301

Remarks:

- Hump-shape structure in point estimates of GPU index remains statistically significant.
- MPU and IP essentially irrelevant.
- CPI only statistically significant at the short to medium length of τ.
- Also, suggests that only government policy uncertainty is driving movements in the term structure of bond volatility.

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